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NORTHEAST CHURCH ROCK MINE
INTERIM REMOVAL ACTION

POST-IRA STATUS SURVEY
INTERIM REMOVAL ACTION
NORTHEAST CHURCH ROCK MINE SITE

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1.0 INTRODUCTION

This report presents the results of the Interim Removal Action (IRA) status surveys (Post-IRA Status Survey of step-out area and Final Status Survey of the unnamed arroyo) conducted at the conclusion of IRA removal activities at the Northeast Church Rock Mine Site (NECR) in Church Rock, New Mexico (the Site) pursuant to the Administrative Order on Consent with EPA Region 9, CERCLA Docket 2009-11. The status surveys consisted of gamma surveying, soil sampling and analysis, and development of a revised correlation between gamma measurements and equivalent Ra-226 concentrations in soil. The Post-IRA Status Survey of the step-out area was conducted in accordance with the *Interim Removal Action Work Plan* (MWH, 2009), as well as the letter to EPA, *IRA Status Survey Sampling Grid and Excavation Schedule for Step-out Areas*, dated October 22, 2009 (MWH), which provided an updated figure showing the gamma surveying and soil sampling locations for the status survey. The Final Status Survey of the unnamed arroyo was conducted in accordance with the *Work Plan for Final Status Survey of the Unnamed Arroyo* (MWH, October 2009) approved by EPA. These status surveys were implemented consistent with MARSSIM guidance (EPA, 2000) and were addressed as Class 1 areas. The objective of the status surveys was to confirm that soils with mean concentrations of Ra-226 in excess of the IRA action level (2.24 pCi/g) were removed from the IRA areas and that the IRA areas have met the MARSSIM release criterion.

2.0 FIELD INVESTIGATION METHODS

2.1 GAMMA SURVEYING

The IRA included excavation of soils from the NECR-1 step-out area and from the unnamed arroyo. The step-out area is relatively flat and soils were typically excavated to not more than approximately one foot, except in certain isolated locations where soils were excavated to greater depths over small confined areas. Conversely, the unnamed arroyo excavation was much deeper (up to 28 feet bgs) and narrow. Therefore, different procedures were used to conduct the Post-IRA Status Survey in the step-out area than those used in the Final Status Survey in the unnamed arroyo, as described in the following sections.

2.1.1 Gamma Correlation Analysis Methods and Instrumentation

A site-specific correlation study for the Post-IRA Status Survey in the step-out area was conducted between gamma radiation levels and Ra-226 concentrations in surface soil using direct gamma radiation measurements. The purpose of the study was to evaluate how well the post-IRA gamma scan results correlate to actual soil sampling results and develop an updated correlation (regression model) for use in future gamma scans to more accurately predict surface soil concentrations.

Previous correlations were developed in September 2007 for the Supplemental Removal Site Evaluation (SRSE dataset) and in July 2009 for the IRA excavation control survey (WP EXC dataset). The 2007 correlation was developed because the SRSE evaluated areas with much lower activity levels than from the mine permit area used in the RSE correlation (2006b). The 2009 correlation was developed to provide a correlation for an alternative laboratory and because the excavation activities could result in changes to the concentration and distribution of Ra-226 in soil, which could change the site-specific correlation between direct gamma radiation levels and Ra-226 concentrations in soil. The IRA Work Plan included developing a revised correlation from the post-IRA excavation sampling data (IRA dataset) to apply to the post-IRA Status Survey.

An Eberline SPA-3 2”x2” NaI Scintillation detector and a Ludlum Model 2221 scaler/ratemeter instrument configuration was used for direct gamma radiation level measurements in accordance with SOP-3 included in the IRA Work Plan. Only the collimated SPA-3 #30 detector and Ludlum 2221 #68782 scaler/ratemeters were used for the Post-IRA Status Survey and correlation data collection. Therefore, the revised correlation was developed only for that specific equipment.

The Ludlum 2221 scaler/ratemeter was calibrated using SOP-1. Optimum operating high voltage for the 2”x2” NaI detector was established by performing a high voltage plateau. The detector efficiencies were determined as described in the SOP-1 using a DOE uranium ore calibration pad near Grants, New Mexico. Following efficiency calibration of the detector, the Minimum Detectable Concentration (MDC) was determined as shown in the SOP-1. The MDC for one minute static measurement for the SPA-3 2"x2" detectors #408522-30, and the Ludlum 44-10 2"x2" detector #276626 was calculated to be less than 0.60 pCi/gm for the collimated detector. The instrumentation calibration documentation is included in Attachment A. Daily function checks of the instrument were performed during the field gamma radiation level measurements. A Differentially Corrected Global Positioning System (DGPS), Magellan MobileMapper CX with TDS SOLO software, was used for determining sampling point location coordinates.

Soil sampling was conducted consistent with the soil sampling procedures in SOP-2. Soil samples were analyzed for Ra-226 by Energy Laboratories, Inc. (ELI) using EPA Method 901.1

The locations of the co-located gamma measurements and collected soil samples used in the correlation analysis (SRSE and the IRA datasets) are shown on Figure 1, *Correlation Soil Sample Locations*. A detailed description of the results of the correlation analysis is included in Section 3.1.

2.1.2 Step-out Area

Subsequent to completion of the excavation within the step-out areas, the Post-IRA Status Survey was conducted. The excavation control survey that was conducted during the IRA construction (see the *Interim Removal Action Completion Report, MWH, 2010*) covered nearly all of the Step-out area; although some areas within the bermed area did not pass this initial survey, as discussed in Section 3. Excavation of soils was conducted in six inch-lifts. After each lift, a radiation scan survey was performed to identify locations that exceeded the action level (2.24 pCi/g). If no points exceeding the action level were measured by the initial excavation scan, one-minute static radiation measurements were collected at regular intervals (approximate grid spacing of 10 by 10 feet) and areas with no exceedances of the action level were deemed complete. Areas above the action level were marked for further excavation. In several small areas gamma measurements remained above the action level even after excavating over two feet deep. At this depth, the elevated gamma measurements could have been due to the geometry of the excavation and shine from the excavation walls, which increases with depth, even where the bottom of the excavation is below the action level. Excavations greater than two feet were required in 17 limited areas, as shown on Figures 2 and 3. In some deeper excavations, the walls of the excavation were wide (low angle) such that the shine from the walls was not significant, and scanning results were below the action level.

Radiation shine was significant in 11 of the deeper excavations, and so excavation was suspended in these areas and additional static gamma radiation measurements were performed at several locations within the excavation, followed by collection of a soil sample (in some cases more than one per excavation) at locations with the highest static gamma radiation measurements. These soil samples were analyzed for Ra-226 using the on-site gamma spectroscopy expedited (few days) analysis, as in the unnamed arroyo. If the on-site gamma spectroscopy results showed Ra-226 below the action level (2.24 pCi/g), a split of the sample was sent to the chemical laboratory (Energy Laboratory) for confirmatory analysis. If the on-site gamma spectroscopy sample showed Ra-226 above the 2.24 pCi/g, additional excavation and rescanning was repeated until activities below the action level were reached.

Once the excavation control survey confirmed that soil exceeding the IRA action level had been removed, static gamma radiation surveying was conducted within the excavated areas as part of the Post-IRA Status Survey. The survey was conducted in accordance with the survey design presented in the *Removal Site Evaluation Work Plan* (MWH, 2006a). The number of survey points was determined using the non-parametric Wilcoxin-Mann-Whitney (WMW) test, in accordance with MARSSIM (this is the terminology used in ProUCL for the same test as the Wilcoxin Rank Sum [WRS] test, which is the terminology used in MARSSIM) to support Data Quality Objectives (DQOs) for Class 1 areas with statistical parameters selected to achieve a low error rate. Consequently, the Post-IRA Status Survey gamma measurements were collected on an 80-foot triangular grid within the IRA excavation limits and cast on a random origin, which resulted in 281 data points. Excavations deeper than approximately two feet required alternate survey methods (e.g., confirmation soil sampling at highest gamma), as presented in Section 2.2.1.

The instrumentation that was used for the Post-IRA Status Survey consisted of a lead collimated 2x2 NaI scintillation detector (such as Eberline SPA-3) for detection of gamma radiation, connected to a portable ratemeter/scaler (such as Ludlum 2221). The gamma radiation levels in count rates (counts per minute) were converted to equivalent Ra-226 concentrations using the regression equation developed from the correlation between gamma measurements and Ra-226 concentrations in soil, as discussed in Section 2.3.

2.1.3 Unnamed Arroyo

Gamma surveying was not used in the unnamed arroyo to conduct the Final Status Survey due to the effect of shine from the geometry of the deep excavation, and the inherent difficulty of conducting gamma surveying within the excavation in a safe and effective manner. Instead, gamma radiation scanning was conducted periodically during construction activities to guide excavation, as described in the *IRA Construction Plan* (MWH, 2009), with additional details provided in the letter to EPA, *Work Plan for Final Status Survey of the Unnamed Arroyo*, dated October 7, 2009 (MWH). The Final Status Survey of the unnamed arroyo included an expanded soil sampling and analysis plan, as described in Section 2.2.2.

To confirm that the excavation had reached the required depth, once the initial field screening indicated that the soils at the bottom of the excavation were at or near the action level (2.24 pCi/g), a sample was collected at a minimum of every 50 feet along the length of the arroyo excavation and from 12 locations along the banks and analyzed by gamma spectroscopy using a Canberra System 100 Gamma Spectroscopy System. The system was set-up in the UNC offices near the mine site, which allowed an estimation of the Ra-226 activity level to be made in one to three days based on the Decay Product In-growth Factor presented in the Gamma Spectroscopy Operating Procedure included in the October 7, 2009 letter to EPA. Once these results indicated excavation in a given area was complete, soil samples were collected for laboratory analysis for the Final Status Survey in the unnamed arroyo, as described in Section 2.2.1.

2.2 SURFACE SOIL SAMPLING AND ANALYSIS

2.2.1 Step-out Area

Surface soil samples were collected for laboratory analysis of Ra-226 at 22 locations within the IRA excavation areas. The soil samples were collected manually as grab samples from 0 to 0.5 feet below ground surface (bgs) within the excavated areas on a regular grid and co-located with the static gamma measurement points that were collected on an 80-ft triangular grid. The surface soil grab samples were collected by carefully removing the top layer of soil or debris to the desired sample depth with a decontaminated spade, shovel, or equivalent. The soil samples were placed into new, appropriately sized stainless steel bowls or aluminum pie tins. In order to ensure proper representation of the material being sampled, homogenization and fractional splitting were used where replicate samples were collected. After homogenization, both the primary and fractional split samples were placed into plastic bags (e.g., ZipLoc® bags), double bagged, and then placed in a cooler for shipment to the laboratory.

As discussed in Section 2.1.2, deeper excavation occurred in some localized areas (up to 8 feet bgs) within the step-out area, as described in the *IRA Completion Report* (MWH, 2010), as shown on Figure 2, *Post-IRA Gamma Survey Results*. In these areas, it was not possible to conduct static gamma surveying for the Post-IRA Status Survey due to the effect of shine from the sidewalls of the excavation. In order to confirm that the IRA was complete in these areas, gamma scanning was performed to identify the location within each excavation with the highest reading and additional soil samples (in addition to the 22 surface soil samples discussed above) were collected. These soil samples were then submitted to the laboratory for analysis of Ra-226.

2.2.2 Unnamed Arroyo

In order to ensure sufficient soil samples to conduct a Final Status Survey, additional soil samples were collected for laboratory analysis along the unnamed arroyo. Soil samples were collected along a transverse transect every 50 feet along the length of the arroyo excavation at the low points of the excavation. Additional samples were collected from the banks of the arroyo along every third transect, on alternating sides of the arroyo, approximately half way up the height of the bank. The excavation was approximately 1,650 feet long and so 45 soil samples were collected for the Final Status Survey (34 bottom samples and 11 bank samples). The soil samples were analyzed for Ra-226 as described in Section 2.2.3.

2.2.3 Chemical Analysis of Soil Samples

The soil samples were submitted to Energy Labs, Inc. (ELI) in Casper, Wyoming and analyzed for Ra-226 using EPA Method 901.1. The reporting limit for all analytical results was 0.1 pCi/g, less than the requested Minimum Detection Limit (MDC) of 0.5 pCi/g. Quality analysis and quality control procedures (QA/QC) are described in the Quality Assurance Project Plan (QAPP), which is included in Appendix A of the *Removal Site Evaluation Work Plan* (MWH, 2006a). The data were verified and validated as per the QAPP, and underwent Level III (90%) and Level IV (10%) data validation (analytical and validation results are included in Section 3.0).

3.0 FINDINGS AND DISCUSSION

3.1 CORRELATION SAMPLING RESULTS AND REGRESSION ANALYSIS

This section presents the results of the correlation sampling and the regression analysis that was subsequently conducted. Results of the correlation and regression are shown in Appendix A. Field forms showing direct gamma radiation level measurements collected during IRA excavation control and IRA status survey for this correlation are included in Appendix B. The direct gamma radiation level measurements and corresponding Ra-226 results for the SRSE correlation from 58 locations (SRSE dataset) are summarized in Table A1 (Appendix A) and shown on Figure 1. The direct gamma radiation level measurements and corresponding Ra-226 results for the April 2009 IRA Work Plan excavation control correlation from 11 locations (WP EXC dataset) are shown in Table A2. Finally, the direct gamma radiation level measurements and corresponding Ra-226 results for the IRA sampling data from 27 locations (IRA dataset) are shown in Table A3.

The revised correlation for the post-IRA status survey was updated consistent with SOP-2 by performing a regression analysis on the soil sample Ra-226 concentration (pCi/g at Y) and the corresponding gamma radiation level (count rate at X) for sampling data from previous correlations and the IRA sampling data using a least-square linear regression and plotting the results.

A regression analysis of the combined data (96 locations) for all three datasets (SRSE, WP EXC and IRA datasets) resulted in an R^2 value of 0.63, lower than the specified value of at least 0.8, as shown in Figure A2. Therefore, this regression analysis consisting of SRSE dataset, WP EXC dataset and the IRA dataset was rejected. A regression analysis of the SRSE correlation dataset (Table A1) updated with the data from IRA dataset (Table A3) resulted in an acceptable R^2 value of 0.92 and a regression analysis equation (model) of Ra-226 = (0.0013×cpm)-4.4967 as shown in Figure A3. A regression analysis data of the WP EXC dataset (Table A2) updated with the data from IRA dataset (Table A3) also resulted in an acceptable R^2 value of 0.93 with a model equation of Ra-226 = (0.0041×cpm)-17.543 as shown in Figure 4. The second regression predicted concentrations of Ra-226 in soil that were biased high.

Since both of these regression analyses (models) produced acceptable R^2 values, they were examined for precision in predicting values by evaluating the residuals. Residuals are estimates of experimental error obtained by subtracting the observed values from the predicted values. The predicted values are calculated from the appropriate regression equation (model) after all the unknown model parameters have been estimated from the measured data. Examining residuals is a key part of all statistical modeling. Carefully examining the residuals can facilitate in evaluating whether assumptions are reasonable and a choice of model is appropriate. Residuals of the 27 post-IRA sampling points (IRA dataset) were calculated for both correlation models as shown in Table A4. Examination of residual behavior is discussed below.

As shown in Table A4, residuals resulting from the SRSE plus the IRA dataset model (Figure A3) are much smaller (ranging from -1.5 to 0.9 with a σ of 0.6) compared to the residuals (ranging from -2.8 to 3.0 with a σ of 1.2) resulting from the WP EXC dataset plus the IRA dataset model (Figure A4).

A histogram plot of residual frequency distribution for the SRSE plus the IRA datasets model (Figure A5) shows these residuals are more normally distributed than the residuals resulted from the WP EXC plus the IRA datasets model (see Figure A6. The SRSE plus the IRA dataset model predicts values with residuals above ±1.0 for only seven percent of the samples, while the WP EXC plus the IRA dataset model predicts vales with residuals above ±1.0 for about 35% of the samples.

The residual examination indicates that the SRSE and the IRA datasets correlation model Ra-226 = (0.0013×cpm)-4.4967 is more accurate than the model resulting from the WP EXC and the IRA datasets. Also, the SRSE and IRA dataset model with a slope of 0.0013 predicts Ra-226 concentrations with lower uncertainties (mean of 0.17 pCi/g) associated with radiation counting as shown in Table A4 compared to the uncertainties (mean of 0.55 pCi/g) predicted by the WP EXC and IRA data set model with a slope of 0.0041.

It appears that any regression analysis which includes the WP EXC dataset results in either an unacceptable R^2 (<0.8) or a model slope that predicts values with larger residuals and uncertainties.
A correlation with regression analysis of just the WP EXC dataset (soil samples analyzed by ALS) resulted in a much lower correlation of gamma scan to soil results; specifically, the gamma scan cpm correlating to the 2.24 pCi/g action level was much lower (by over 500 cpm) than the correlation developed using the RSE dataset(i.e., the correlation developed using this dataset yielded Ra-226 results that were biased high). Nevertheless, the correlation resulting from the WP EXC dataset was used for the excavation control survey in the step-out area as a conservative approach during the IRA construction.

Based on the correlation discussed above, the following regression model equation resulting from the SRSE dataset updated with the IRA dataset (Figure A3) is more accurate for converting the direct gamma radiation level measurement (CPM for the collimated SPA-3 detector) to equivalent Ra-226 concentration in soil:

$$\text{Ra-226 (pCi/g)} = (0.0013 \times \text{cpm}) - 4.4967$$

The results of this correlation analysis can be used to more accurately predict surface soil concentrations which exceed the action level using gamma radiation level measurements.

3.2 STATIC GAMMA SURVEY RESULTS

A total of 281 static gamma radiation level measurements were collected between October 22, 2009 and January 6, 2010 within the IRA excavation areas, not including the unnamed arroyo, as shown on Figure 2. The static gamma radiation measurements and equivalent Ra-226 concentrations are listed in Table 2, *Post-IRA Static Gamma Radiation*

Measurements. A statistical summary of the results of these measurements as equivalent Ra-226 concentrations in pCi/g follows:

- Mean 1.6
- Median 1.5
- Standard Deviation 0.7
- Minimum <0.6
- Maximum 6.6
- 25^{th} percentile 1.3
- 75^{th} percentile 1.6

As discussed in the *Removal Site Evaluation Report* (MWH, 2007a), the gamma radiation survey data collected for the IRA provides data of a quality sufficient for field screening. Data collected with field instruments have the potential for error and low accuracy, particularly at low concentrations and are considered to be an estimated value.

The results of the gamma measurements showed that only about 10% of the locations (32) exceeded 2.24 pCi/g and less than 5% of the locations (11) exceeded 3.0 pCi/g, the $DCGL_{EMC}$. The $DCGL_{EMC}$ was specified by EPA for the RSE and is greater than the action level ($DCGL_W$) by approximately four times (0.76) the standard deviation (0.18) of the background reference area dataset from the RSE (MWH, 2006b). All of the locations exceeding 2.24 pCi/g were from the southern portion of the IRA area on the hillside and the southeastern corner of the IRA area (see Figure 2). Those locations exceeding 3.0 pCi/g were clustered on the southwestern portion of the hillside immediately adjacent to the NECR-1 pad, plus three locations in the southeastern corner of the IRA area.

In order to evaluate whether the mean concentration in the IRA area is statistically different than the mean of the background area, the two datasets were compared to each other using the WMW test, in accordance with MARSSIM. The WMW test was used with the following parameters:

- Null Hypothesis (Ho): IRA Area Mean/Median >= Background Mean/Median Plus Substantial Difference, S (Form 2)

- Alternative Hypothesis (HA): IRA Area Mean/Median < Background Mean/Median Plus Substantial Difference, S

- Substantial Difference (S): $DCGL_W$ (1.14 pCi/g)

- Confidence Level: 95 percent

Static gamma measurements from the IRA area were statistically analyzed in two groups:

1. gamma measurements from the entire IRA excavation area (excluding the unnamed arroyo) consisting of 281 measurements; and

2. gamma measurements only from the excluded area within the berm constructed during the IRA around the hillside consisting of 112 measurements.

Each of these groups of data was compared to the background reference area laboratory analyzed Ra-226 concentrations using the WMW test. The outputs from ProUCL showing the results of the tests are included in Appendix C. In both cases, the p-value was less than 0.001, and so at a 95% confidence level ($\alpha = 0.05$), the null hypothesis is rejected. The conclusion from the test is that the means of the IRA static gamma datasets (entire area and excluded area) are less than the mean of the background reference area and, therefore, the IRA area (both datasets) passes the MARSSIM release criterion based on the correlated gamma measurements.

Consistent with MARSSIM, the gamma measurements were evaluated to assess if there were potentially any areas of elevated residual radioactivity (i.e., those exceeding the $DCGL_{EMC}$) that might result in a dose or risk exceeding the release criterion. The results of the gamma surveys confirmed some measurements along the southern edge of the IRA area did exceed the $DCGL_{EMC}$, but only in a few small areas. Statistical analysis of all the gamma survey results confirm that these few areas do not result in a dose or risk exceeding the release criterion and that the MARSSIM release criterion has been achieved for the step-out area.

3.3 SURFACE SOIL ANALYTICAL RESULTS

Surface soil samples were collected from 70 locations within the IRA areas, including the unnamed arroyo, subsequent to completion of the IRA excavation activities, and were analyzed for Ra-226. The locations of each of the soil samples and analytical results are shown on Figure 3, *Surface Soil Analytical Results*. The analytical results are tabulated in Table 3, *Post-IRA Soil Sample Analytical Results*. The laboratory analytical reports and the results of the data validation are included in Appendix D, *Laboratory Analytical Reports and Data Validation Results*. A statistical summary of the results of the Ra-226 analyses in pCi/g follows:

Group	Count	Mean	Median	Std Dev	Minimum	Maximum	25th %	75th %
Unnamed Arroyo	46	1.0	1.0	0.5	0.4	2.2	0.5	1.3
Step-out Area	24	1.5	1.5	0.6	0.5	3.5	1.1	1.8

The results of the deeper excavation samples (those with location IDs starting with "Z") from the step-out area ranged from 0.4 to 2.2 pCi/g with a mean of 1.1 pCi/g, as summarized in Table 3 and shown on Figure 3.

These data show that within the unnamed arroyo, Ra-226 concentrations were less than 2.24 pCi/g at 100% of the sample locations (see Figure 3). The dataset from the unnamed arroyo was statistically compared to Ra-226 concentrations from the background reference area using the WMW (see Appendix C) for completeness, even though it is not necessary to do so, since all concentrations were below 2.24 pCi/g. The conclusion from these results and the WMW test is that the removal action of the unnamed arroyo was completed and the area passes the MARSSIM release criterion.

Within the step-out area, Ra-226 concentrations were less than 2.24 pCi/g at all but two surface soil locations (all those from the deeper excavations were less than 2.24 pCi/g). One sample collected from the southeast portion of the IRA area was reported at 2.3 pCi/g and a second sample located in the central portion of the area was reported at 3.5 pCi/g, as shown on Figure 3. At the location of the sample that contained 3.5 pCi/g (SSPT-213) the static gamma measurement conducted for the status survey correlated value was 2.1 pCi/g. So to confirm the laboratory result of 3.5 pCi/g the sample was recounted twice, all three results obtained were 3.5 to 3.6 pCi/g.

In order to confirm that the mean soil concentration of Ra-226 in the IRA step-out area (excludes the unnamed arroyo) is statistically different than the mean of the background area, the results (n=24) of the soil analyses (Table 3) were statistically compared using the WMW test, in the same manner and using the same test parameters as for the static gamma measurements (see Section 3.1). The outputs from ProUCL showing the results of the tests are included in C. The results of the test showed that the p-value was less than 0.001, and so at a 95% confidence level ($\alpha = 0.05$), the null hypothesis is rejected. The conclusion from the test is that the means of the Post-IRA Status Survey soil analytical results is less than the mean of Ra-226 concentrations in the background reference area. Therefore, the IRA step-out area passes the MARSSIM release criterion.

4.0 CONCLUSIONS

This report presents the results of the Post-IRA Status Survey of the step-out area and Final Status Survey of the Arroyo conducted at the conclusion of IRA removal activities at the Northeast Church Rock Mine Site in Church Rock, New Mexico pursuant to the Administrative Order on Consent CERLCA, Docket 2009-11. The status survey consisted of gamma surveying, soil sampling and analysis, and development of a revised correlation between gamma measurements and equivalent Ra-226 concentrations. The Post-IRA Status Survey of the step-out area was conducted in accordance with the *Interim Removal Action Work Plan* (MWH, 2009), and the Final Status Survey of the arroyo was conducted in accordance with the *Work Plan for Final Status Survey of the Unnamed Arroyo* (MWH, October 2009). The objective of the surveys was to confirm that soils with mean Ra-226 concentrations in excess of the IRA action level (2.24 pCi/g) were removed from the IRA areas and that the IRA areas meet the MARSSIM release criterion.

The results of the gamma surveying and the soil analyses from the step-out area and unnamed arroyo show that the IRA of the unnamed arroyo and the step-out area meets the MARSSIM release criterion post-removal. The results of the gamma surveys and soil sampling confirmed that only a few small areas exceed the $DCGL_{EMC}$ and statistical analysis of all the survey and soil sampling results confirm that the MARSSIM release criterion has been achieved for the step-out area and the unnamed arroyo.

5.0 REFERENCES

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TABLES

FIGURES

APPENDICES

APPENDIX A

REVISED IRA CORRELATION ANALYSIS TABLES AND FIGURES

APPENDIX B

GAMMA SURVEY CALIBRATION DATA AND SURVEY FIELD FORMS

B-1

INSTRUMENT CALIBRATION L2221-SPA

B-2

INSTRUMENT DAILY FUNCTION CHECK LOG

B-3

EXC CONTROL STATIC GAMMA SURVEY FIELD LOG

B-4

POST IRA STATUS GAMMA SURVEY FIELD FORM

B-5

ON-SITE GAMMA SPEC SOIL SAMPLING ROUTING LOG

B-6

IRA SOIL SAMPLING LOG

APPENDIX C

RESULTS OF WILCOXIN-MANN-WHITNEY TESTS USING PROUCL 4.0

APPENDIX D

LABORATORY ANALYTICAL REPORTS AND DATA VALIDATION RESULTS

(PROVIDED ELECTRONICALLY)